

## METHANOL VEHICLES

For this study, three different M85 FFV models were tested: the Dodge Spirit, the Dodge Intrepid, and the Ford Econoline van. Because the results for the Ford van were reported in a previous publication,<sup>8</sup> they are not included in this report.

Table 8 provides a summary comparison of the emissions from the FFVs tested on M85 to the same vehicles tested on RFG. In the table, the highlighted blocks indicate that there was a 95% statistically significant difference (based on the ANOVA) in emissions from the two fuels tested. A plus sign in the block means that the emissions from the M85 test were higher than those from the RFG test, and a minus sign means that the M85 emissions were lower. These results are shown for all of the measured emissions from the Dodge Spirit and the Intrepid at the respective test laboratories. For instance, during the first round (Round 1) of testing, the CO emissions from the Dodge Intrepid were higher for M85 than RFG (plus sign), but the difference was not statistically significant at the 95% confidence level (not highlighted). A more detailed and quantitative discussion of the specific results for each vehicle is presented in the following sections, but it may also be useful to consider a more qualitative view of the general trends for the methanol tests.

Some of the results (such as HC, greenhouse gases, aldehydes, and the fuel economy calculation) were very consistent across vehicle models, test laboratories and test rounds, others

(CO, NO<sub>x</sub>, and evaporative HC) were more mixed. Although both vehicle models are FFVs produced by Dodge, the two models may employ different engine calibrations in order to meet differing performance and emissions expectations.

In general, both vehicles tended to have significantly (evaluated at 95%) lower NMHCE, total hydrocarbon (THC), CO<sub>2</sub>, CH<sub>4</sub>, and CH<sub>3</sub>CHO

emissions, as well as lower fuel economy, when tested on M85. On the other hand, both vehicles tended to have significantly higher HCHO emissions and energy equivalent fuel economy (mpeg) when tested on M85. There appeared to be very little difference (not statistically significant at 95%) in CO and evaporative HC emissions between the two fuels. The NO<sub>x</sub> emissions tended to be higher

**Table 8. Summary Comparison of Average Emission Results from M85 versus RFG**

|                              | Dodge Intrepid |         | Dodge Spirit |         |         |         |
|------------------------------|----------------|---------|--------------|---------|---------|---------|
|                              | Lab 1          |         | Lab 1        |         | Lab 3   |         |
|                              | Round 1        | Round 2 | Round 1      | Round 2 | Round 1 | Round 2 |
| <b>Regulated Emissions</b>   |                |         |              |         |         |         |
| NMHCE                        | -              | -       | -            | -       | -       | -       |
| THC                          | -              | -       | -            | -       | -       | -       |
| CO                           | +              | +       | -            | -       | -       | -       |
| NO <sub>x</sub>              | +              | +       | +            | -       | +       | +       |
| <b>Evaporative Emissions</b> |                |         |              |         |         |         |
| THC                          | +              | +       | -            | -       | -       | +       |
| <b>Greenhouse Gases</b>      |                |         |              |         |         |         |
| CO <sub>2</sub>              | -              | -       | -            | -       | -       | -       |
| CH <sub>4</sub>              | -              | -       | -            | -       | -       | -       |
| <b>Aldehydes</b>             |                |         |              |         |         |         |
| HCHO                         | +              | +       | +            | +       | +       | +       |
| CH <sub>3</sub> CHO          | -              | -       | -            | -       | -       | -       |
| <b>Fuel Economy</b>          |                |         |              |         |         |         |
| mpg                          | -              | -       | -            | -       | -       | -       |
| mpeg                         | +              | +       | +            | +       | -       | +       |

“+” Indicates results from M85 tests were higher than RFG tests

“-” Indicates results from M85 tests were lower than RFG tests

Highlighted blocks indicate a significant statistical difference.

from M85, but this result was not consistent across all test categories.

One possible reason for finding mixed results and fuel effects that are not statistically significant is that a FFV is not optimized for either fuel, but is instead designed to perform acceptably on a wide range of fuel blends. An inherent benefit of the flexible fuel design is the capability for convenient fueling on gasoline or methanol where it is available. An inherent drawback to this design is that the vehicle cannot be optimized to take advantage of some of the beneficial properties of methanol. One obvious example of this is that these vehicles are designed with a compression ratio that is suitable for gasoline. A vehicle optimized for methanol could be designed with an increased compression ratio that would take advantage of methanol's higher octane rating and provide increased power and efficiency.

A similar evaluation of the general trends from the more limited set of HC speciation tests (shown in Table 9) is very consistent across vehicles and labs. These results give an indication of how the chemical composition of the hydrocarbon emissions differ between the two fuels. With regard to the four air toxic HC covered here,

**Table 9. Summary Comparison of Average Speciated Hydrocarbon Results from M85 versus RFG**

|                         | Intrepid | Spirit |       |
|-------------------------|----------|--------|-------|
| Air Toxics              | Lab 1    | Lab 1  | Lab 3 |
| HCHO                    | +        | +      | +     |
| CH <sub>3</sub> CHO     | -        | -      | -     |
| 1,3-butadiene           | -        | -      | -     |
| Benzene                 | -        | -      | -     |
| Total PWT               | -        | -      | -     |
| <b>Ozone Reactivity</b> |          |        |       |
| OFP                     | -        | -      | -     |
| SR                      | -        | -      | -     |

“+” Indicates results from M85 tests were higher than RFG tests

“-” Indicates results from M85 tests were lower than RFG tests

Highlighted blocks indicate a significant statistical difference.

the vehicles tested on M85 tended to emit much higher levels of HCHO, and significantly lower levels of CH<sub>3</sub>CHO, 1,3-butadiene, and benzene compared to the same vehicles tested on RFG. When the potency weighting factors are applied to these emissions levels and totaled as the total PWT emissions, the M85 results were significantly lower than the RFG results.

The detailed speciation of the HC was also used to compare the tendency for HC emissions to react and

form ozone. The OFP and the SR of the HC emissions from the M85 tests were significantly lower than those from the same vehicles tested on RFG. The detailed evaluation of hydrocarbon emissions from M85 and RFG was consistent for both the toxic emissions and the parameters related to ozone formation for both vehicle models at the two laboratories that performed hydrocarbon speciation.

## DODGE INTREPID

The 1995 Dodge Intrepid (shown in Figure 3) is a passenger car equipped with a 3.3 L V6 engine. This vehicle model employs electronically controlled multi-point fuel injection and is equipped with a three-way catalyst for exhaust emissions control. The flexible-fuel version was certified to the EPA federal Tier 0 emissions standard and the standard gasoline version was certified to federal Tier 1 levels (refer to Table 1, page 2). We performed two rounds of tests on the Dodge Intrepids at Lab 1. There were 17 standard gasoline Intrepids and 16 FFVs tested in both rounds. Mileage ranges and average



Argonne National Laboratory/PIXO

**Figure 3. 1995 Dodge Intrepid**

**Table 10. Odometer Readings for the Dodge Intrepid**

|                     | FFV   |        | Gasoline |        |
|---------------------|-------|--------|----------|--------|
| Round               | 1     | 2      | 1        | 2      |
| No. vehicles tested | 16    | 16     | 17       | 17     |
| Odometer (miles)    |       |        |          |        |
| Average             | 5,128 | 14,332 | 5,661    | 17,231 |
| Maximum             | 9,558 | 26,084 | 18,783   | 42,738 |
| Minimum             | 3,047 | 9,653  | 3,336    | 5,929  |

odometer readings for the Intrepids are shown in Table 10. The complete listing of the vehicles tested and the detailed emissions test results are included in Appendix A.

### *Regulated Emissions*

Table 11 shows the average emissions results for the Dodge Intrepid. The values shown include the averages for the FFV model tested on M85 and

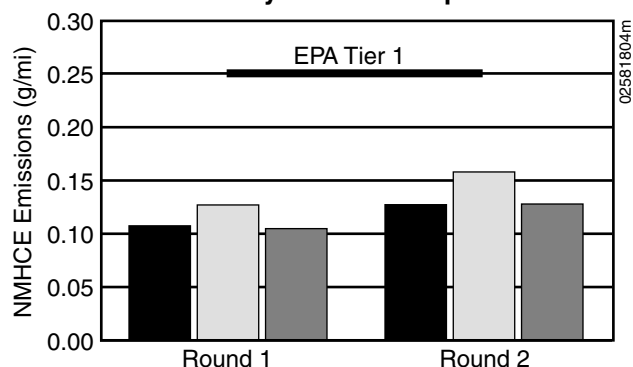
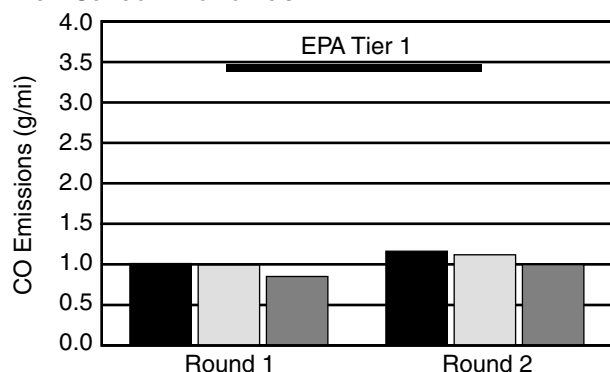
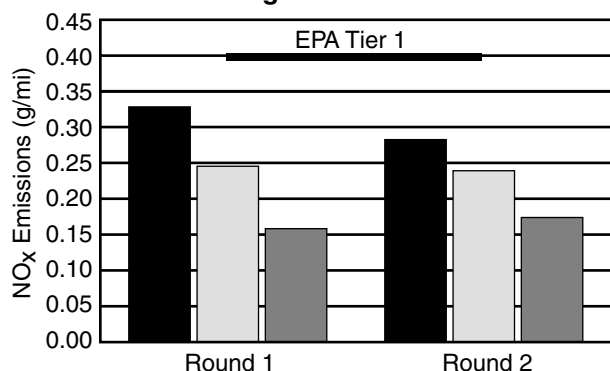
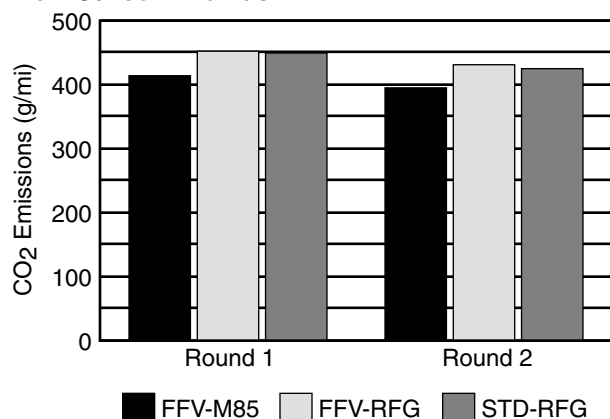
RFG and the percent difference between the averages. An indication is also given on whether the difference between the average results is statistically significant as determined by the ANOVA. All average regulated emissions shown here were well below the Tier 1 emissions standards. Figure 4 shows the regulated and CO<sub>2</sub> emissions for the Intrepid along with the Tier 1 50,000-mile certification

standard. In general, when comparing the M85 and RFG regulated emissions for the FFV Dodge Intrepid, NMHCE emissions from the M85 tests were lower, there was very little difference in CO emissions, and the NO<sub>x</sub> emissions from the M85 tests were substantially higher.

More specifically, the FFV Intrepid showed a statistically significant decrease in HC emissions when tested on M85. In Round 1, the average emissions from the M85 tests were 16% lower; in Round 2, they were 19.6% lower than those from the same vehicles tested on RFG. When comparing the FFV tested on RFG to the standard Intrepid, the FFV had higher NMHCE emissions in both test rounds. For the FFVs, there tended to be a small, but statistically significant increase in NMHCE emissions from Round 1 to Round 2.

**Table 11. Average Emissions Results from the Dodge Intrepid**

|                                       | Round 1 |         |                    |                   | Round 2 |         |                    |                   |
|---------------------------------------|---------|---------|--------------------|-------------------|---------|---------|--------------------|-------------------|
|                                       | FFV-M85 | FFV-RFG | Percent Difference | Sig. Fuel Effect? | FFV-M85 | FFV-RFG | Percent Difference | Sig. Fuel Effect? |
| <b>Regulated Emissions (g/mi)</b>     |         |         |                    |                   |         |         |                    |                   |
| NMHCE                                 | 0.107   | 0.127   | -15.7%             | y                 | 0.127   | 0.158   | -19.62%            | y                 |
| THC                                   | 0.112   | 0.149   | -24.7%             | y                 | 0.132   | 0.182   | -27.6%             | y                 |
| CO                                    | 1.01    | 0.99    | 2.0%               | n                 | 1.16    | 1.12    | 3.9%               | n                 |
| NO <sub>x</sub>                       | 0.328   | 0.245   | 33.9%              | y                 | 0.283   | 0.239   | 18.2%              | y                 |
| <b>Evaporative Emissions (g/Test)</b> |         |         |                    |                   |         |         |                    |                   |
| Total Evaporative                     | 0.876   | 0.669   | 30.9%              | y                 | 0.816   | 0.712   | 14.6%              | n                 |
| <b>Greenhouse Gases (g/mi)</b>        |         |         |                    |                   |         |         |                    |                   |
| CO <sub>2</sub>                       | 413.9   | 452.3   | -8.5%              | y                 | 395.0   | 431.2   | -8.4%              | y                 |
| CH <sub>4</sub>                       | 0.016   | 0.028   | -42.7%             | y                 | 0.017   | 0.031   | -43.6%             | y                 |
| <b>Aldehydes (mg/mi)</b>              |         |         |                    |                   |         |         |                    |                   |
| HCHO                                  | 16.0    | 1.9     | 742.1%             | y                 | 17.62   | 2.52    | 604.8%             | y                 |
| CH <sub>3</sub> CHO                   | 0.17    | 0.45    | -62.0%             | y                 | 0.23    | 0.59    | -60.9%             | y                 |
| <b>Fuel Economy</b>                   |         |         |                    |                   |         |         |                    |                   |
| mpg                                   | 11.66   | 19.19   | -39.2%             | y                 | 12.16   | 20.13   | -39.6%             | y                 |
| mpeg                                  | 20.21   | 19.19   | 5.3%               | y                 | 21.07   | 20.13   | 4.7%               | y                 |

**4a: Non-Methane Hydrocarbon Equivalent****4b: Carbon Monoxide****4c: Oxides of Nitrogen****4d: Carbon Dioxide**

**Figure 4. Emissions results from the Dodge Intrepid**

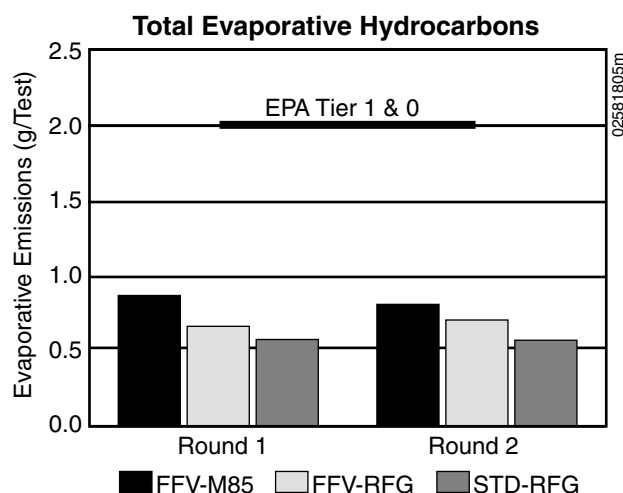
The CO and NO<sub>x</sub> emissions do not show the same trend as NMHCE. The CO emissions from the FFVs tested on M85 were not statistically different from the results of the FFVs tested on RFG and there was little difference between rounds. There was a statistically significant increase in NO<sub>x</sub> emissions for the FFV tested on M85. In Round 1, the NO<sub>x</sub> emissions from the M85 tests were 33.9% higher; in Round 2, they were 18.2% higher than those from the RFG tests on the same vehicles. The NO<sub>x</sub> emissions for the FFV Intrepid show a decrease in the second round that was significant for M85, but was not statistically significant for RFG. NO<sub>x</sub> emissions from the standard gasoline vehicles tested on RFG were substantially lower than those from the FFVs tested on the same fuel.

**Evaporative Emissions**

The average evaporative emissions for the FFV Intrepid are listed in Table 11 and shown graphically in Figure 5. The average evaporative HC were well below the 2-g standard for the FFVs and the gasoline vehicles. When comparing evaporative emissions results for the FFV Intrepid tested on M85 to the same vehicles tested on RFG, the M85 evaporative emissions were 30% higher in Round 1, and 14.6% higher in Round 2. The higher evaporative emissions for the FFV tested on M85 is expected, because the Reid vapor pressure (RVP) of the methanol fuel is higher than that of RFG (see Table 5). The difference in evaporative emissions was statistically significant in Round 1, but was not in Round 2. The average evaporative emissions for the conventional Intrepids were lower than the averages for the FFV on both fuels. There was no significant difference between Round 1 and 2 for the FFV on either fuel.

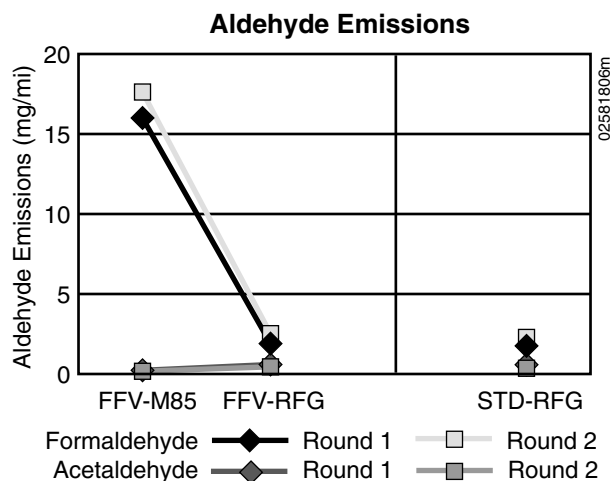
**Greenhouse Gases**

The average CO<sub>2</sub> emissions for the Intrepids are listed in Table 11 and shown in Figure 4d. Results from Rounds 1 and 2



**Figure 5. Evaporative emissions results from the Dodge Intrepid**

followed the same trend between the fuels and vehicle types, with very little difference between the rounds. The CO<sub>2</sub> emissions from the FFV tested on M85 were approximately 8.5% lower than those from the same vehicles tested on RFG. The results for the standard model were similar to the FFV on RFG. Average CH<sub>4</sub> emissions were very low (less than 0.05 g/mi). For the FFV tested on M85, the CH<sub>4</sub> emissions were approximately 43% lower than those from the FFV tested on RFG in both rounds.



**Figure 6. Aldehyde emissions from the Dodge Intrepid**

### Aldehydes

Figure 6 shows the comparison of aldehyde emissions for the Dodge Intrepid. This graph shows that the formaldehyde emissions were much higher from the FFV when tested on M85. Formaldehyde is a primary decomposition product from methanol combustion; therefore, the higher numbers are expected. For Round 1, average formaldehyde emissions were 742% higher in the M85 tests, and for Round 2, the M85 results were 605% higher than the RFG results. Acetaldehyde emission levels for the FFV tested on M85 were approximately 61% lower than the results for the same vehicles tested on RFG, but the levels of acetaldehyde emissions were very low (less than 0.6 mg/mi).

### Potency-Weighted Toxics and Ozone-Forming Potential

Over the two rounds of emissions tests performed, full HC speciation was performed on a total of six FFV Intrepids and four standard gasoline vehicles. Table 12 lists the average measured toxic emissions and the PWT values and percent difference for the four air toxic compounds. The potency weighting is discussed on page 2 and the factors are shown in Table 3. The aldehyde values listed are the averages for the speciated vehicles only. Figure 7 shows the comparison of these compounds and the total PWT for the Dodge Intrepids. When comparing PWT for the FFV Dodge Intrepids tested on M85 compared to the same vehicles tested on RFG, the HCHO emissions were significantly higher, but CH<sub>3</sub>CHO, 1,3-butadiene, and ben-

zene were significantly lower when tested on M85. Total PWT emissions for the FFVs tested on M85 were 16.2% lower than those from the same vehicles tested on RFG.

Table 13 lists the average OFP and SR for the FFV Intrepid. Figure 8 illustrates an important consideration when comparing HC emissions for the two test fuels. Both OFP and SR were significantly lower for the FFV when tested on M85. Although the average NMOG emissions from the M85 tests were 85% higher than the RFG tests, the OFP was 33.7% lower and the SR was 65.2% lower for the M85 tests. In other words, although the NMOG emissions from this subset of vehicles were higher, the potential to form ozone based on the exhaust composition is significantly lower. The exhaust from M85 is less reactive in forming ozone in the

**Table 12. Toxic Emissions from the Dodge Intrepid**

|                     | FFV-M85                |        | FFV-RFG                |        | Percent Difference | Sig. Fuel Effect? |
|---------------------|------------------------|--------|------------------------|--------|--------------------|-------------------|
|                     | Measured Value (mg/mi) | PWT    | Measured Value (mg/mi) | PWT    |                    |                   |
| HCHO                | 15.65                  | 0.72   | 2.00                   | 0.092  | 682.5%             | y                 |
| CH <sub>3</sub> CHO | 0.20                   | 0.0016 | 0.488                  | 0.0039 | -59.0%             | y                 |
| 1,3-butadiene       | 0.113                  | 0.113  | 0.813                  | 0.813  | -86.2%             | y                 |
| Benzene             | 0.919                  | 0.028  | 3.956                  | 0.119  | -76.8%             | y                 |
| Total               | 16.882                 | 0.861  | 7.257                  | 1.027  | -16.2%             | y                 |

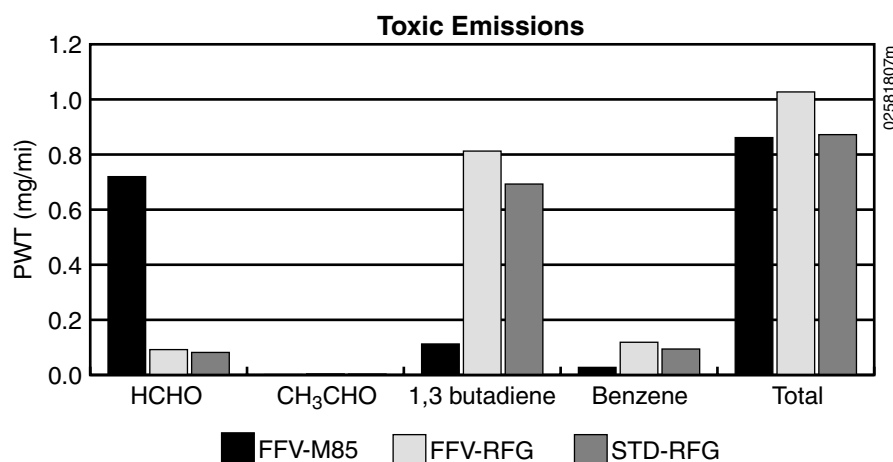


Figure 7. PWT emissions from the Dodge Intrepid

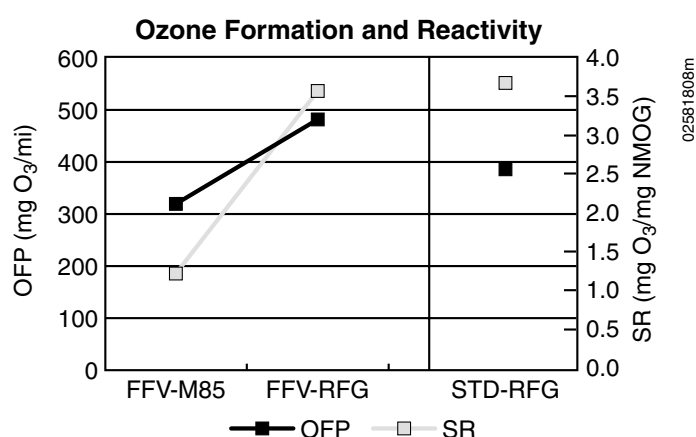


Figure 8. OFP and SR for the Dodge Intrepid

Table 13. OFP for the Dodge Intrepid

|                                 | FFV-M85 | FFV-RFG | Percent Difference | Sig. Fuel Effect? |
|---------------------------------|---------|---------|--------------------|-------------------|
| NMOG (mg/mi)                    | 257.94  | 139.76  | 84.6               | y                 |
| OFP (mg O <sub>3</sub> /mi)     | 319.5   | 481.69  | -33.7%             | y                 |
| SR (mg O <sub>3</sub> /mg NMOG) | 1.248   | 3.587   | -65.2%             | y                 |

atmosphere. The OFP and the SR for the gasoline model tested on RFG were similar to those of the FFV tested on RFG.

### Fuel Economy

The fuel economy for the FFV Intrepid was approximately 12 mpg when operating on M85 and 20 mpg on gasoline. This is a decrease of approximately 39% for the FFV tested on M85 for both rounds. This is

expected because methanol has a lower volumetric energy content than gasoline. The energy content of the M85 (64,600 Btu/gal) is 58% of the RFG (111,960 Btu/gal). In other words, it takes approximately 1.7 gallons of M85 to travel the same distance as 1 gallon of gasoline. When the values are adjusted to account for this difference, the average fuel economy for the FFV Intrepid on M85 is 20 mpeg in Round 1 and 21 mpeg in

Round 2. In other words, the M85 tests showed a 5% improvement in energy equivalent fuel economy over RFG for Round 1 and a 4.7% improvement for Round 2. The FFV on gasoline had similar fuel economy numbers to the conventional model. An important consideration for most drivers is the range of the vehicle. Because of the difference in energy content of the fuels, the FFV operating on M85 will not travel as far as when using gasoline. For this reason, many manufacturers increase the size of the tank to help offset this difference. The FFV Intrepid and the gasoline control Intrepid tested here, however, both had 18-gallon fuel tanks. Based on the fuel economy for the FTP-75, the gasoline control vehicle has an approximate range of 356 miles; the FFV has a range of 214 miles on M85 and 354 miles on gasoline.

### DODGE SPIRIT

The 1993 Dodge Spirit (shown in Figure 9) is a passenger car equipped with a 2.5 L, I6 engine with multi-point fuel injection. Although both the FFV and gasoline Spirits were certified to federal Tier 0 emissions standards, the majority of the emissions results are below the more stringent Tier 1 levels. This report covers the two rounds of testing performed on the Dodge Spirits at Labs 1 and 3. Lab 2 tested the Dodge Spirit in only 1 round and the results can be found in a previous publication.<sup>8</sup> At Lab 1, 21 FFV Spirits and 24 gasoline controls were tested in both rounds. At Lab 3, the FFV Spirits totaled 22 and the gasoline controls 20 in both rounds. Mileage ranges and average odometer readings for each vehicle type and round are listed in Tables 14 and 15. The complete data set can be found in Appendix A.



**Figure 9. The 1993 M85 Dodge Spirit**

**Table 14. Odometer Readings for the Dodge Spirit Tested at Lab 1**

|                         | FFV    |        | Gasoline |        |
|-------------------------|--------|--------|----------|--------|
| Round                   | 1      | 2      | 1        | 2      |
| No. vehicles tested     | 21     | 21     | 24       | 24     |
| <b>Odometer (miles)</b> |        |        |          |        |
| Average                 | 8,803  | 17,073 | 12,208   | 27,834 |
| Maximum                 | 18,203 | 29,679 | 35,757   | 61,638 |
| Minimum                 | 3,704  | 7,683  | 4,339    | 10,036 |

**Table 15. Odometer Readings for the Dodge Spirit Tested at Lab 3**

|                         | FFV    |        | Gasoline |        |
|-------------------------|--------|--------|----------|--------|
| Round                   | 1      | 2      | 1        | 2      |
| No. vehicles tested     | 22     | 22     | 20       | 20     |
| <b>Odometer (miles)</b> |        |        |          |        |
| Average                 | 14,030 | 24,240 | 16,063   | 28,035 |
| Maximum                 | 26,058 | 38,506 | 28,005   | 47,989 |
| Minimum                 | 4,080  | 8,746  | 5,743    | 9,467  |

### *Regulated Emissions*

Tables 16 and 17 list the average emissions results for the FFV Dodge Spirits tested at Lab 1 and Lab 3. Included in the tables are the averages for the FFV tested on M85 and RFG, along with the percent difference between the averages. The statistical significance of the fuel effect was

determined using the ANOVA analysis. All average regulated emissions for the Spirits tested at both labs were well below the Tier 0 emission standard and in most cases, also below the more stringent Tier 1 levels. (The EPA emissions certification standards are shown in Table 1 on page 2.) Figures 10 and 11 show the regulated

and CO<sub>2</sub> emissions for the Spirits tested at Labs 1 and 3. In general, when comparing the regulated emissions for M85 and RFG tests for the Dodge Spirit, NMHCE emissions from the M85 tests were lower, CO emissions from the M85 tests were slightly lower, and NO<sub>x</sub> emissions for the M85 tests tended to be higher.

Average HC emissions showed similar patterns on the vehicles tested at both labs. The NMHCE emissions for the FFV operating on M85 were significantly less than those from the same vehicles tested on gasoline (Figures 10a and 11a). For Lab 1, the difference was 17% during Round 1 and 27% in Round 2. For Lab 3, the difference between the fuels was even larger, approximately 30.5% in both rounds. NMHCE emissions for the conventional Spirits tested at both labs were lower than the levels of the FFV operating on either fuel. The difference in NMHCE emissions from Round 1 to Round 2 tended to be not significant at the 95% confidence level.

The CO emissions from both labs are shown in Figures 10b and 11b. The average values at Lab 3 were higher than the averages at Lab 1, but they follow the same pattern. At both labs the standard gasoline model had lower CO emissions than the FFV on either fuel. The FFV had lower CO emissions when tested on M85, but the difference between the two fuels was only significant for Round 2 at Lab 1. At Lab 1, the FFV on M85 was 1% lower in Round 1 and approximately 11% lower in Round 2. The FFVs tested at Lab 3 showed a difference of approximately 10% lower on M85 for both rounds. Average CO emissions showed increases from Round 1 to Round 2 that were statistically significant for both fuels at both labs. All CO emissions averages were well below the Tier 0 and Tier 1 standard of 3.4 g/mi.

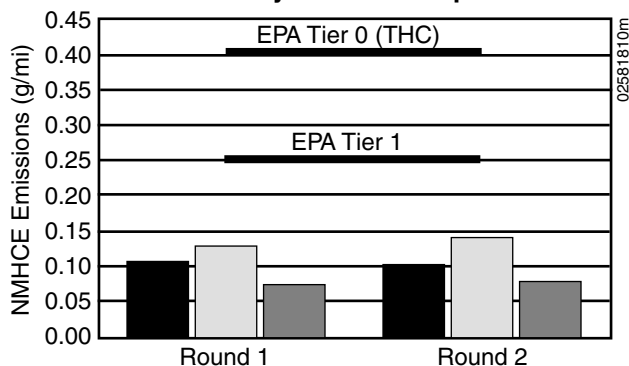
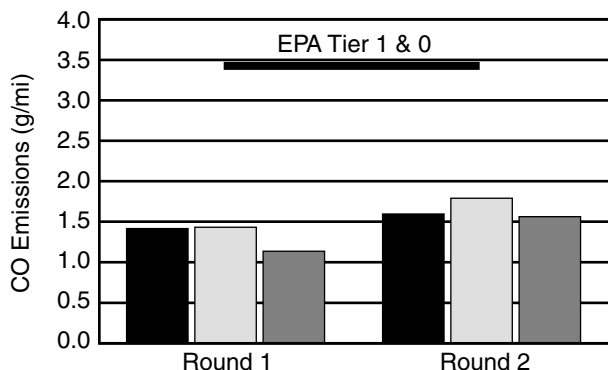
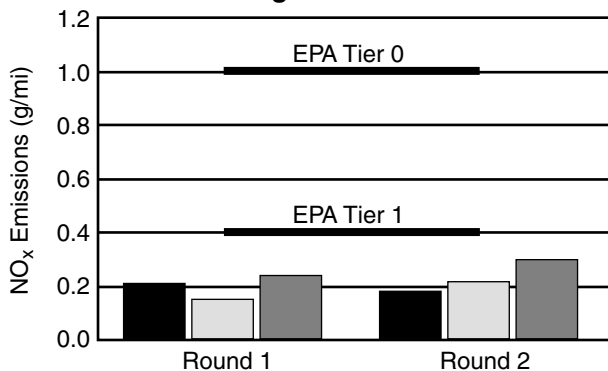
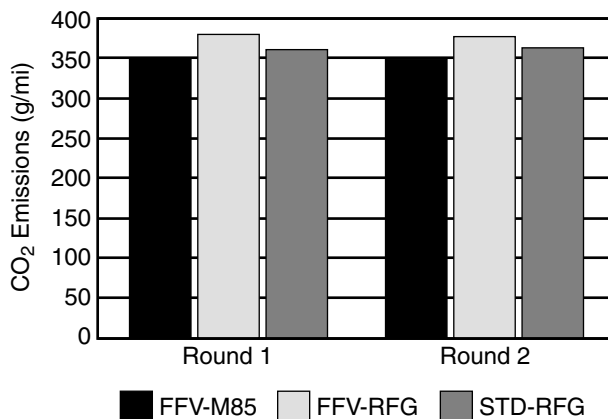
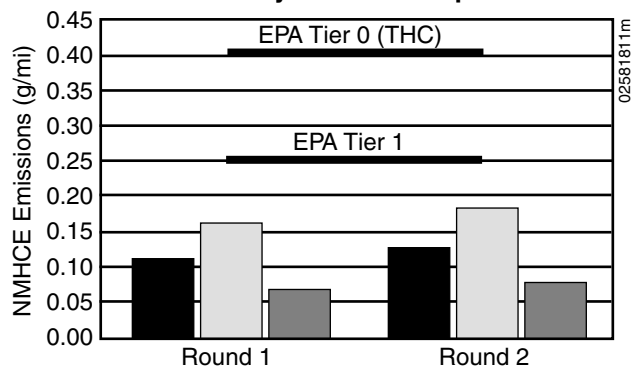
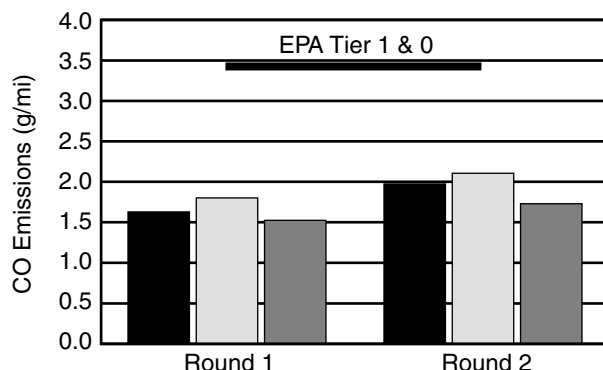
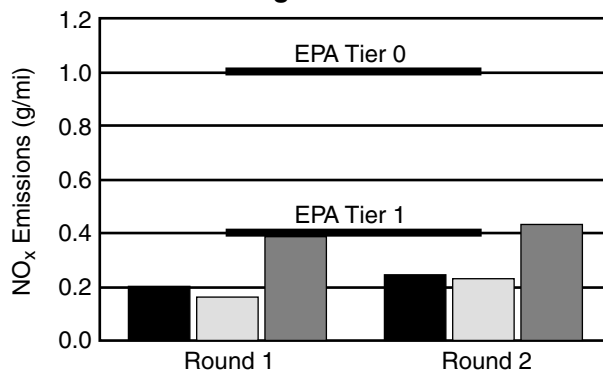
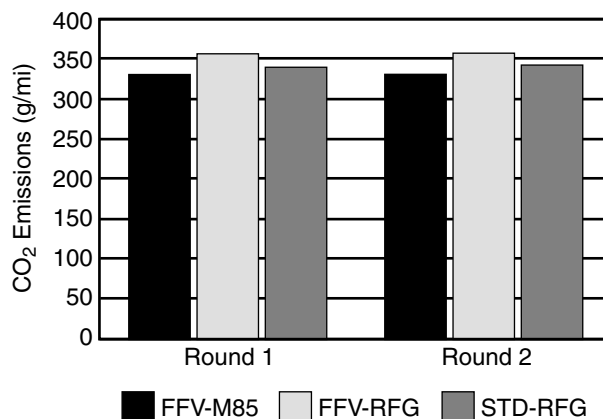
Table 16. Average Emissions Results from the Dodge Spirit Tested at Lab 1

|                                       | Round 1 |         |                    |                   | Round 2 |         |                    |                   |
|---------------------------------------|---------|---------|--------------------|-------------------|---------|---------|--------------------|-------------------|
|                                       | FFV-M85 | FFV-RFG | Percent Difference | Sig. Fuel Effect? | FFV-M85 | FFV-RFG | Percent Difference | Sig. Fuel Effect? |
| <b>Regulated Emissions (g/mi)</b>     |         |         |                    |                   |         |         |                    |                   |
| NMHC                                  | 0.108   | 0.130   | -16.9%             | y                 | 0.104   | 0.142   | -26.9%             | y                 |
| THC                                   | 0.112   | 0.151   | -25.8%             | y                 | 0.111   | 0.168   | -33.8%             | y                 |
| CO                                    | 1.43    | 1.45    | -1.2%              | n                 | 1.61    | 1.81    | -10.9%             | y                 |
| NO <sub>x</sub>                       | 0.212   | 0.151   | 40.4%              | y                 | 0.182   | 0.219   | -16.9%             | y                 |
| <b>Evaporative Emissions (g/Test)</b> |         |         |                    |                   |         |         |                    |                   |
| Total Evaporative                     | 0.708   | 0.724   | -2.21%             | n                 | 0.78    | 0.887   | -12.1%             | n                 |
| <b>Greenhouse Gases (g/mi)</b>        |         |         |                    |                   |         |         |                    |                   |
| CO <sub>2</sub>                       | 350.3   | 379.5   | -7.7%              | y                 | 348.6   | 376.8   | -7.5%              | y                 |
| CH <sub>4</sub>                       | 0.015   | 0.026   | -43.1%             | y                 | 0.016   | 0.031   | -49.8%             | y                 |
| <b>Aldehydes (mg/mi)</b>              |         |         |                    |                   |         |         |                    |                   |
| HCHO                                  | 12.7    | 1.47    | 763.9%             | y                 | 12.4    | 1.42    | 771.8%             | y                 |
| CH <sub>3</sub> CHO                   | 0.31    | 0.50    | -37.8%             | y                 | 0.19    | 0.39    | -50.9              | y                 |
| <b>Fuel Economy</b>                   |         |         |                    |                   |         |         |                    |                   |
| mpg                                   | 13.56   | 22.82   | -40.6%             | y                 | 13.8    | 23.02   | -40.1%             | y                 |
| mpeg                                  | 23.5    | 22.82   | 3.0%               | y                 | 23.92   | 23.02   | 3.9%               | y                 |

Table 17. Average Emissions Results from the Dodge Spirit Tested at Lab 3

|                                       | Round 1 |         |                    |                   | Round 2 |         |                    |                   |
|---------------------------------------|---------|---------|--------------------|-------------------|---------|---------|--------------------|-------------------|
|                                       | FFV-M85 | FFV-RFG | Percent Difference | Sig. Fuel Effect? | FFV-M85 | FFV-RFG | Percent Difference | Sig. Fuel Effect? |
| <b>Regulated Emissions (g/mi)</b>     |         |         |                    |                   |         |         |                    |                   |
| NMHC                                  | 0.113   | 0.162   | -30.6%             | y                 | 0.128   | 0.184   | -30.4%             | y                 |
| THC                                   | 0.061   | 0.188   | -67.5%             | y                 | 0.061   | 0.220   | -72.5%             | y                 |
| CO                                    | 1.63    | 1.80    | -9.6%              | n                 | 1.98    | 2.11    | -10.5%             | n                 |
| NO <sub>x</sub>                       | 0.207   | 0.166   | 24.7%              | y                 | 0.251   | 0.236   | 6.4%               | n                 |
| <b>Evaporative Emissions (g/Test)</b> |         |         |                    |                   |         |         |                    |                   |
| Total Evaporative                     | 0.371   | 0.48    | -22.7%             | n                 | 1.207   | 1.067   | 13.1%              | n                 |
| <b>Greenhouse Gases (g/mi)</b>        |         |         |                    |                   |         |         |                    |                   |
| CO <sub>2</sub>                       | 331.3   | 357.2   | -7.3%              | y                 | 331.5   | 357.9   | -7.4%              | y                 |
| CH <sub>4</sub>                       | 0.014   | 0.028   | -48.5%             | y                 | 0.015   | 0.031   | -52.0%             | y                 |
| <b>Aldehydes (mg/mi)</b>              |         |         |                    |                   |         |         |                    |                   |
| HCHO                                  | 9.15    | 1.16    | 688.8%             | y                 | 10.4    | 1.63    | 538.0%             | y                 |
| CH <sub>3</sub> CHO                   | 0.19    | 0.35    | -45.7%             | y                 | 0.29    | 0.47    | -38.3%             | y                 |
| <b>Fuel Economy</b>                   |         |         |                    |                   |         |         |                    |                   |
| mpg                                   | 12.78   | 24.07   | -46.9%             | y                 | 14.46   | 24.0    | -39.8%             | y                 |
| mpeg                                  | 22.15   | 24.07   | -8.0%              | y                 | 25.06   | 24.0    | 4.4%               | y                 |

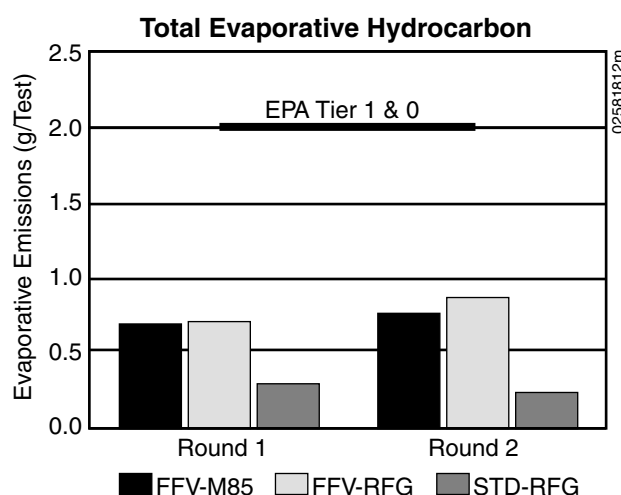


**10a: Non-Methane Hydrocarbon Equivalent****10b: Carbon Monoxide****10c: Oxides of Nitrogen****10d: Carbon Dioxide****Figure 10. Emissions results from the Dodge Spirit tested at Lab 1****11a: Non-Methane Hydrocarbon Equivalent****11b: Carbon Monoxide****11c: Oxides of Nitrogen****11d: Carbon Dioxide****Figure 11. Emissions results from the Dodge Spirit tested at Lab 3**

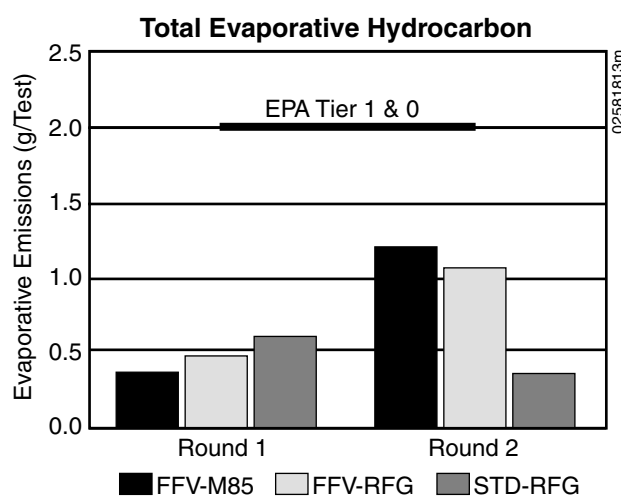
The NO<sub>x</sub> emissions for the Spirits tested at Lab 1 showed different patterns in the two rounds. During Round 1, the NO<sub>x</sub> emissions from the FFV operating on M85 were 40% higher than those from the same vehicles tested on RFG. The standard model tested on RFG had an even higher NO<sub>x</sub> average. In Round 2, the average NO<sub>x</sub> emissions for the FFV tested on M85 were 17% lower than the average when tested on RFG. The standard model again tested higher than the FFV on both fuels. The Spirits tested at Lab 3 showed similar trends. In Round 1, the FFV Spirits tested on M85 had 25% higher NO<sub>x</sub> emissions than when they were tested on RFG. In Round 2, the average for M85 was only 6% higher than the average for RFG. The values for the standard model Spirits were much higher than the FFV Spirits in both rounds. All NO<sub>x</sub> values were well below the Tier 0 levels.

### Evaporative Emissions

Average evaporative emissions for the Dodge Spirits are listed in Tables 16 and 17. Figures 12 and 13 graphically illustrate these values. The average evaporative HC for the FFV and standard gasoline Spirits were well below the standard of 2 g per test. When comparing the FFV Spirits tested on M85 to the same vehicles tested on RFG, both labs showed no significant difference between the two fuels. The conventional Spirits tested lower than the FFV Spirits on either fuel with one exception. At Lab 3 during Round 1, the conventional Spirits had higher evaporative emissions than the FFV. There was an increase in evaporative emissions between Rounds 1 and 2 for the FFV tested on both fuels at Lab 1, but the difference was not significant at the 95% confidence level. At Lab 3, the FFV on both fuels showed statistically significant increases in Round 2.



**Figure 12. Evaporative emissions results from the Dodge Spirit tested at Lab 1**



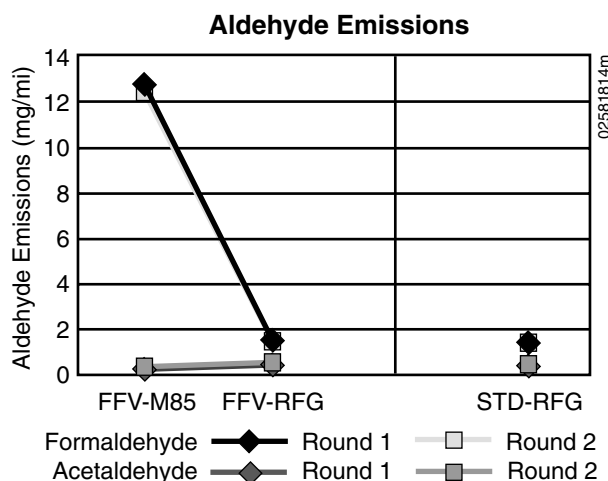
**Figure 13. Evaporative emissions results From the Dodge Spirit tested at Lab 3**

Because of the high variability of evaporative results, outliers were not deleted from the data sets. Round 2 evaporative results for the FFV Spirits tested at Lab 3 increased significantly over Round 1 for both fuels. This was not consistent with the results from Lab 1, and warranted a closer look. The evaporative results for the FFV Spirits tested at Lab 1 showed only 2 outliers, which had little effect on the final averages. The evaporative results from the Spirits tested at Lab 3, however, revealed several apparent outliers. Most of those data points were well above the EPA limit of 2 g per test; the highest

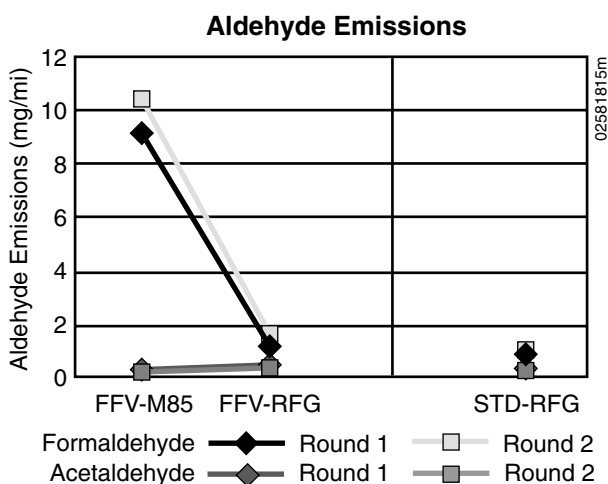
was 6.9 g total. When those outliers were removed from the data set, the results were more consistent from lab to lab and round to round.

### Greenhouse Gases

The average CO<sub>2</sub> emissions are shown in Figures 10d and 11d. Both labs showed the same patterns, with the FFV on M85 having the lowest CO<sub>2</sub> emissions and the FFV on RFG the highest. The percent difference between the FFV on M85 and on RFG was approximately 7% for both labs during both rounds. These were statistically significant differences at the 95% confidence level. Average



**Figure 14. Aldehyde emissions from the Dodge Spirit tested at Lab 1**



**Figure 15. Aldehyde emissions from the Dodge Spirit tested at Lab 3**

CO<sub>2</sub> emissions at Lab 1 showed a decrease between Round 1 and Round 2 that was not significant for M85, but was significant for RFG. Average CO<sub>2</sub> emissions at Lab 3 showed an increase from Round 1 to Round 2 for both fuels that was not statistically significant at the 95% confidence level.

Although the differences in CH<sub>4</sub> emissions between fuels were statistically significant for both rounds at both labs, the measured amounts were all below 0.04 g/mi. The average CH<sub>4</sub> values for the FFV tested on M85 were 43% to 52% less than those from the same vehicles tested on RFG. Both labs show

increases in CH<sub>4</sub> during Round 2 for M85 and RFG. These differences between rounds were not significant for M85, but they were significant for RFG at Lab 1.

### Aldehydes

The average aldehyde emissions for the Dodge Spirits are shown in Figures 14 and 15. For both labs, the formaldehyde emissions were six to eight times higher in the FFVs tested on M85. As with the Intrepid, this is expected, because formaldehyde is a primary decomposition product from methanol combustion. At Lab 1, the percent increase for the M85 tests was 764% and 772% for Rounds 1

and 2, respectively. At Lab 3, the increase was 689% and 538% for the two rounds. The average formaldehyde emissions for the FFV and the standard model (both tested on RFG) were similar.

Acetaldehyde emissions from the M85 and RFG tests were quite low (all below 0.005 g/mi). The acetaldehyde emissions were lowest on the FFV tested on M85 for both labs. At Lab 1, the FFV tested on M85 in Round 1 showed a decrease in acetaldehyde emissions of 38% and in Round 2, the decrease was 51% when compared to the FFV tested on RFG. Lab 3 showed similar decreases for M85 compared to RFG of 46% and 38% in Rounds 1 and 2, respectively. The average acetaldehyde emissions for the standard models was higher than the FFV tested on M85, but lower than those from the FFV tested on RFG for both labs.

### Potency-Weighted Toxics and Ozone-Forming Potential

During this study, full speciation was performed on 10 FFV Spirits and 9 standard gasoline Spirits. Tables 18 and 19 list the average measured toxic emissions and the average PWT for the FFV Dodge Spirits tested at Labs 1 and 3. Aldehyde values are the average of the speciated vehicles only. Figures 16 and 17 illustrate the differences graphically. When comparing the FFV tested on M85 to the same vehicles tested on RFG, there was a significant increase in formaldehyde emissions, and significant decreases in acetaldehyde, 1,3-butadiene, and benzene. Total PWT for Lab 1 FFV Spirits tested on M85 was 23% lower than the total PWT for the RFG tests. At Lab 3, the difference was 46% lower for the M85 tests. All of these differences between fuels were statistically significant at the 95% confidence level. The total PWT for the gasoline control Spirits was substantially lower than the PWT for

**Table 18. Toxic Emissions from the Dodge Spirit Tested at Lab 1**

|                     | FFV-M85                |       | FFV-RFG                |       | Percent Difference | Sig. Fuel Effect? |
|---------------------|------------------------|-------|------------------------|-------|--------------------|-------------------|
|                     | Measured Value (mg/mi) | PWT   | Measured Value (mg/mi) | PWT   |                    |                   |
| HCHO                | 14.035                 | 0.646 | 1.687                  | 0.078 | 731.0%             | y                 |
| CH <sub>3</sub> CHO | 0.252                  | 0.002 | 0.488                  | 0.004 | -50.0%             | y                 |
| 1,3-butadiene       | 0.10                   | 0.10  | 0.80                   | 0.80  | -87.5%             | y                 |
| Benzene             | 1.042                  | 0.031 | 4.40                   | 0.132 | -90.2%             | y                 |
| Total               | 15.429                 | 0.779 | 7.375                  | 1.013 | -23.1%             | y                 |

**Table 19. Toxic Emissions from the Dodge Spirit Tested at Lab 3**

|                     | FFV-M85                |        | FFV-RFG                |        | Percent Difference | Sig. Fuel Effect? |
|---------------------|------------------------|--------|------------------------|--------|--------------------|-------------------|
|                     | Measured Value (mg/mi) | PWT    | Measured Value (mg/mi) | PWT    |                    |                   |
| HCHO                | 9.725                  | 0.447  | 1.538                  | 0.071  | 532.3%             | y                 |
| CH <sub>3</sub> CHO | 0.275                  | 0.0022 | 0.475                  | 0.0038 | -42.1%             | y                 |
| 1,3-butadiene       | 0.174                  | 0.174  | 0.997                  | 0.997  | -82.6%             | y                 |
| Benzene             | 1.695                  | 0.051  | 6.023                  | 0.181  | -71.9%             | y                 |
| Total               | 11.869                 | 0.674  | 9.033                  | 1.252  | -46.2%             | y                 |

**Table 20. OFP for the Dodge Spirit Tested at Lab 1**

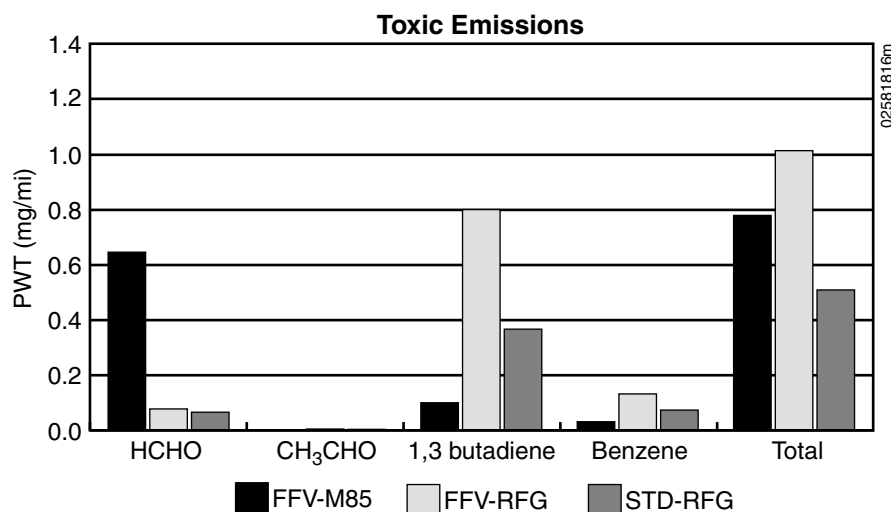
|                                 | FFV-M85 | FFV-RFG | Percent Difference | Sig. Fuel Effect? |
|---------------------------------|---------|---------|--------------------|-------------------|
| NMOG (mg/mi)                    | 191.70  | 151.80  | 26.3%              | y                 |
| OFP (mg O <sub>3</sub> /mi)     | 263.74  | 380.63  | -30.7%             | y                 |
| SR (mg O <sub>3</sub> /mg NMOG) | 1.385   | 2.908   | -52.4%             | y                 |

**Table 21. OFP for the Dodge Spirit Tested at Lab 3**

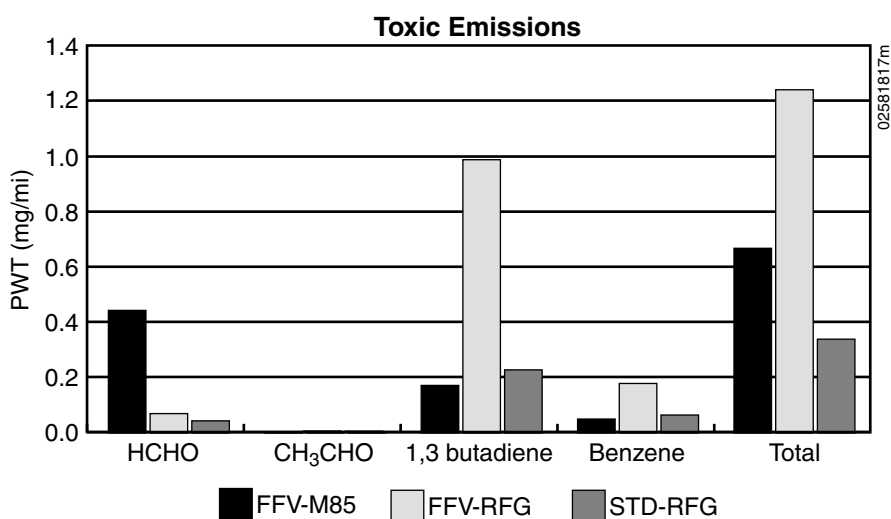
|                                 | FFV-M85 | FFV-RFG | Percent Difference | Sig. Fuel Effect? |
|---------------------------------|---------|---------|--------------------|-------------------|
| NMOG (mg/mi)                    | 242.56  | 219.18  | 10.7%              | n                 |
| OFP (mg O <sub>3</sub> /mi)     | 332.66  | 749.19  | -55.6%             | y                 |
| SR (mg O <sub>3</sub> /mg NMOG) | 1.387   | 3.581   | -61.9%             | y                 |

the FFV Spirit tested on either fuel. This trend was consistent among labs. The decrease in PWT appears to be a direct result of the decrease in NMHC for the gasoline Spirits compared to the FFV Spirit tested on RFG. The decrease in HC may result from the differences in calibration of the vehicle models.

Tables 20 and 21 list the NMOG, OFP, and SR for the Spirits at both labs. Figures 18 and 19 graphically illustrate these averages. The NMOG emissions from the M85 tests were higher than those from the RFG tests on this vehicle subset, but the OFP and SR were lower. As with the Intrepids, although the NMOG emissions were higher, the ozone formed from these emissions would tend to be less than that formed from the RFG emissions. The OFP and SR were significantly lower for the FFV when tested on M85. The FFV Spirits



**Figure 16. PWT emissions from the Dodge Spirit tested at Lab 1**

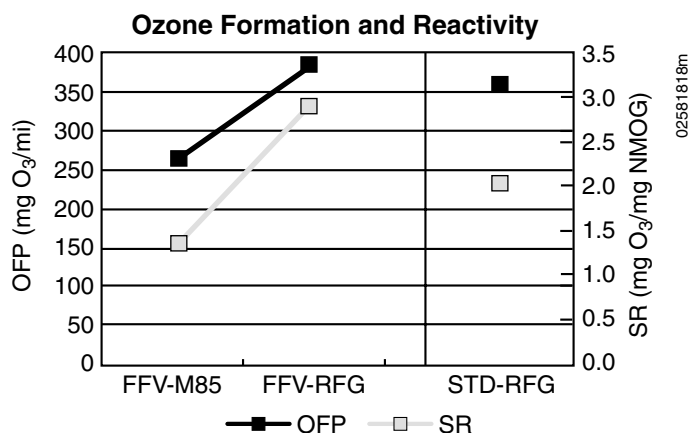


**Figure 17. PWT emissions from the Dodge Spirit tested at Lab 3**

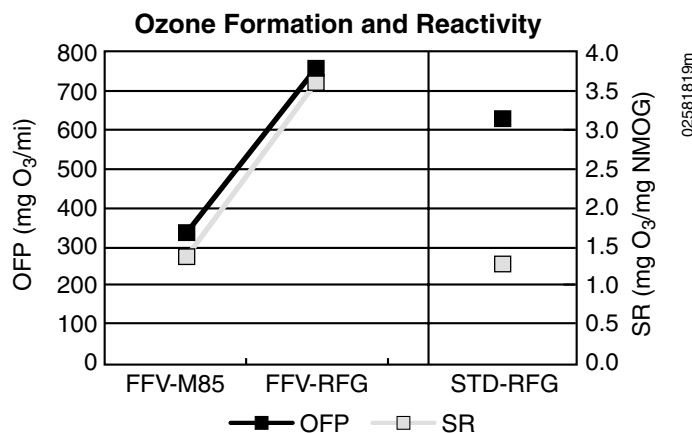
tested at Lab 1 on M85 showed a 31% reduction in OFP and a 52.4% reduction in SR. Lab 3 values showed a similar finding; OFP was 55.6% lower in the M85 tests and SR was 61.8% lower.

### Fuel Economy

When tested on M85, the fuel economy on the Dodge Spirits was significantly less than when the same vehicles were tested on gasoline. For Lab 1, there was a decrease of about 40% for both rounds. The Dodge Spirits tested at Lab 3 averaged 47% lower in Round 1 and 40% lower in Round 2 when tested on M85. As with the Intrepids, the energy equivalent fuel economy for the Spirits on M85 was much higher. On an energy equivalent basis, the FFV tested on M85 was 3% to 4% more energy efficient than when it was tested on RFG at Lab 1. The Spirits tested at Lab 3 during Round 1 were approximately 8% less energy efficient in Round 1, but were 4.4% more energy efficient in Round 2. Unlike the Intrepid, Dodge increased the tank size of the FFV Spirit to help offset the difference in energy content of the fuels. The tank on the gasoline control holds 16 gallons for a range of approximately 390 miles. The FFV tank holds 18 gallons for a range of approximately 245 miles on M85 and 420 miles on gasoline.



**Figure 18. OFP and SP for the Dodge Spirit tested at Lab 1**



**Figure 19. OFP and SR for the Dodge Spirit tested at Lab 3**